EUV Optical Component Characterization for The Cosmic Hot Interstellar Plasma Spectrometer

Richelieu Hemphill
Space Sciences Laboratory, University of California, Berkeley, CA 94720

Introduction

The Cosmic Hot Interstellar Plasma Spectrometer (CHIPS) is the first small platform satellite observatory NASA University-Class Explorer Mission. It is a three-axis stabilized, solar panel array powered spacecraft designed to operate for one year. It weighs approximately 60 kg and is the size of a large suitcase. As of February 2003, CHIPS is orbiting about 590 km above the Earth, and is the first mission to use end-to-end satellite operations via the Internet. It was designed and built at the Space Sciences Laboratory of the University of California at Berkeley. CHIPS's optical components were each characterized at the Lawrence Berkeley National Laboratory (LBNL) Advance Light Source (ALS).

The instrument is studying the low density gas that fills the space between the stars, the Interstellar Medium (ISM), by conducting an all-sky spectral survey of the diffuse background of our local astronomical neighborhood from 90 Å to 260 Å. The majority of the radiated ISM power is believed to be contained in this poorly explored extreme-ultraviolet (EUV) region of the electromagnetic spectrum near 170 Å. At this wavelength, the spectrometer has a peak resolution of 130. From these measurements, CHIPS will determine local ISM electron temperature, ionization conditions and cooling mechanisms.

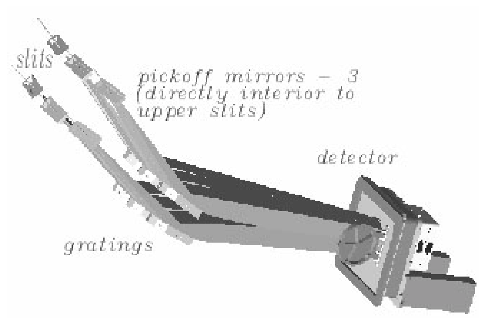

Figure 1: The six light path channels of CHIPS.

Optics

CHIPS consists of six light path channels focussed on one microchannel plate detector (Figure 1). Each channel consists of an entrance slit, 7 cm in length and a selectable width of either 0.025 cm or 0.1 cm. Interior to each slit, there is a variable line spaced Rh coated, reflective optic grating with a 147.8 cm cylindrical figure of radius blazed for the first inside order. The precise line density variation, σ, and blaze angles are given by,

$$\sigma = \frac{\sigma_0}{1 + \frac{2b_2 w}{R} + \frac{3b_3 w^2}{R^2} + \frac{4b_4 w^3}{R^3}} \tag{1}$$

where,

Dispersion Coordinate W (cm)	Central Spacing σ_0 (Å)	b_2	b_3	b_4	Blaze Angle (deg)
4.5 to 4.0	2.113E+5	-1.64907	-4.795874	-70.9946	1.3
1.33 to 4.0	5555.56	-1.64907	-4.795874	-70.9946	1.3
-1.33 to 1.33	5555.56	-1.64907	-4.795874	-70.9946	2.5
-4.0 to –1.33	5555.56	-1.64907	-4.795874	-70.9946	3.7
-4.5 to 4.0	2.113E+5	-1.64907	-4.795874	-70.9946	3.7

All gratings are third generation replicas of a mechanically ruled master, have a zeodur base material and gross dimensions of 90 mm360 mm. The upper three spectrometer channels each contain a 75 mm x 75 mm flat metal pick-off mirror between the slit and grating to coalign the field of view with the lower three non-mirrored channels. Due to the possibility of the pick-off mirrors temporarily facing the ram direction, Ir was choosen as the mirror coating due to its superior resistance to atomic O degradation, and its reasonable reflectivity at the mirror's grazing incidence angle of 3.5° for CHIPS bandpass.[1]

A thin-film filter set (Figure 2) of four distinct panels is mounted in front of the detector to define four unique bandpasses and attenuate scattered light. The design and fabrication criteria was to minimize the detector response from bright geocoronal and interplanetary emission at 1216 Å, 584 Å and 304 Å, while maximizing inband sensitivity within filter material limits prescribed by launch vehicle and orbital enviornmental constraints.

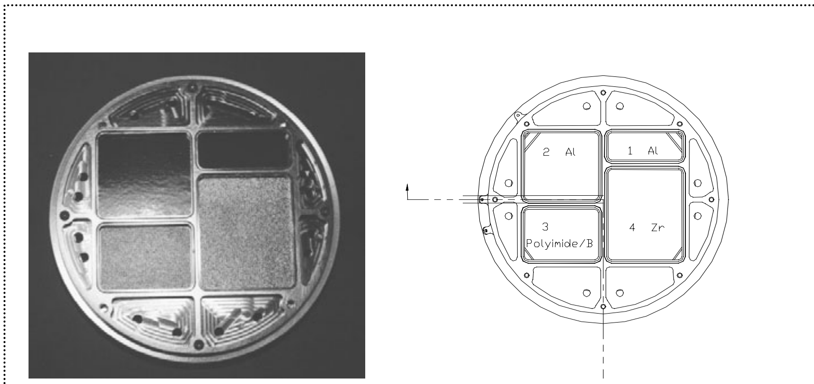

Figure 2: CHIPS thin-film filter array.

Measurements

The transmission of each thin-film filter, reflectivity of each grating and pick-off mirror for CHIPS was measured at the LBNL ALS calibrations and standards beamline 6.3.2 in Berkeley, California. All reflectometer motions were controlled independently by computer so a scan script was used for most reflectivity measurements. The light incident on all samples were estimated to be greater than 90% transverse electric polarization and had an approximate spot size of 100 µm by 1 mm.

The reflectivity of each of three pick-off mirrors was measured at a fixed grazing incidence angle of 3.5°. The results are shown in Figure 3. The reflectivity of all three mirrors is relatively constant from about 130 Å to 260 Å with a maximum relative change of about 5% near the astronomically important 170 Å line.

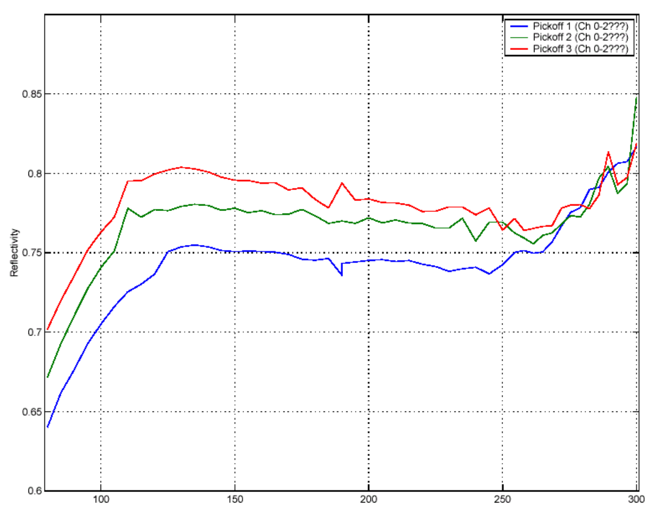

Figure 3: Measured reflectivity vs wavelength of pick-off mirrors at 3.5° incident graze angle.

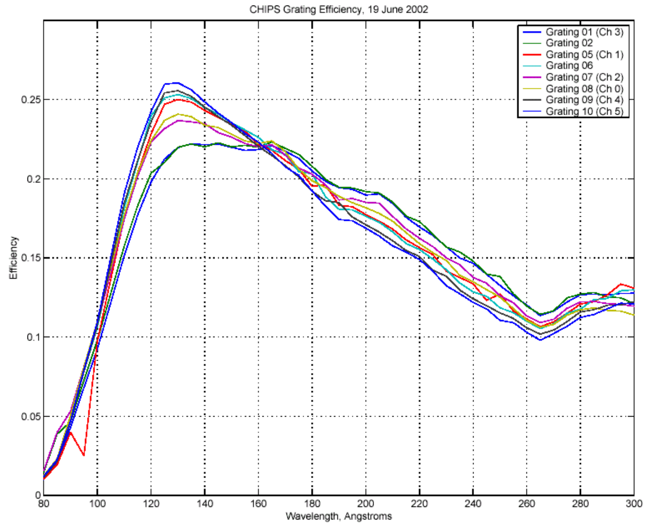

Figure 4: Measured 1st inside order efficiency vs wavelength for CHIPS gratings

The absolute 1st inside order efficiency near each grating's center for eight potential CHIPS flight gratings was measured between 80 Å and 300 Å in 5 Å steps at an input graze angle of 14°. As shown in Figure 4, the blaze in 1st order is measured near 135 Å for all eight gratings. Near the astronomically important 170 Å line, there is only a small 1st order efficiency variation from about 21% to 22% between each of eight gratings. Also, a usable 1st order efficiency stretching over several hundred angstroms (≥ 10% for 100 Å to 260 Å) implies a very broad grating blaze function.

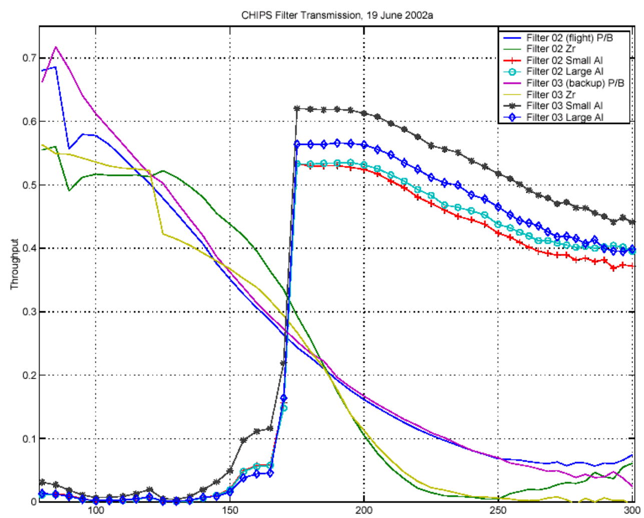

Figure 5: Measured transmission vs wavelength for CHIPS filters

The transmission from 80 Å to 300 Å was measured for two thin-film filter sets as shown in Figure 2. Each set had four filter panels made of ~1500 Å thick Al (2 panels each set), ~1000 Å thick Zr and Polyimide/B with a thickness ratio of ~600 Å/500 Å respectively. The transmission of the astronomically important 170 Å line is reasonable in the Zr filter with an approximate value of 30% and about doubled in the Al filter with an approximate value near 60%.

References

1. P.N. Peters, J.C. Gregory and J.T. Swann, "Effects on optical systems from interactions with oxygen atoms in low earth orbits, " Appl. Opt. **25**, 1290-1298 (1986).

Research for this project was supported by National Aeronautics and Space Administration UNEX grant NAG5-5213.
Principal investigator: Mark Hurwitz, Space Sciences Laboratory, University of California, Berkeley. Telephone: 510-642-1579.
Email: markh@ssl.berkeley.edu.